Benchmark Test Results
for
Low Mach Number Flows: Broken dam problem

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To begin, I report preliminary results obtained using a fluid-mixture type algorithm proposed previously by myself. In short, the main ingredients in this algorithm are:

1. Both the air and water are considered as compressible materials and their thermodynamic behavior can be described well by a stiffened gas equation of state of the form

$$p(\rho, e) = (\gamma - 1)\rho e - \mathcal{B},$$

   where for air we have $\gamma = 1.4$, $\mathcal{B} = 0$, and for water we have $\gamma = 4.4$, $\mathcal{B} = 6 \times 10^8$Pa.

2. The basic model system to be solved numerically are the Euler equations of gas dynamics for conserved variables and an additional set of "effective" equations for the material quantities.

3. An operator-splitting approach is used to deal with the model system with gravitational sources in that a standard wave propagation method is employed for the homogeneous part of model equations and a second order Runge-Kutta ODE solver is employed for the source term.

Figure 1 shows the time history of the water column height at the left boundary and also the leading water front position at the bottom boundary, where the numerical results obtained using high-resolutin version of the method with three different meshes are in comparison with the experimental results. Note that the computed solutions are in reasonable agreement with the experimental results as the mesh is refined. In Fig. 2, pseudocolor plots for the volume fraction are shown at six different times $t = 0$, 0.066, 0.109, 0.164, 0.222, and 0.281s with the use of three different mesh sizes. From the figure, when the meshes are of size 100×30 and 200×60, the existence of a kink-like structure near the corner of the water colume is an anomalous behavior which should be removed by a chosen numerical method. Table 1 shows the computational cost in CPU time for the runs presented in Figs. 1 and 2, where an HP xw9400 Workstation with AMD Dural-Core Opteron 2220 2.8GHz under the Linux redhat operating system is used for the simulation. From the table, it is without doubt that we need to have a faster solver for the numerical resolution of this problem.

Note that I have used the same initial and boundary conditions as done by Murrone and Guillard, see reduce5eq-results or preconditioned-reduce5eq-results.

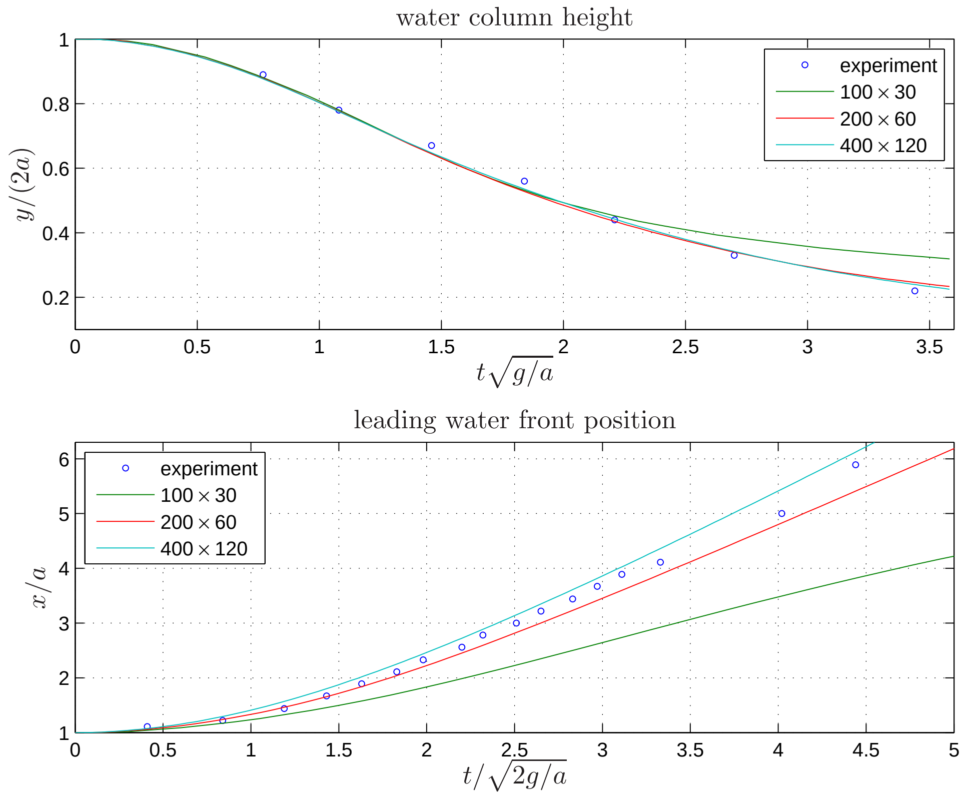

Figure 1: Comparison between numerical solutions and experimental results for the broken dam problem. On the top, results on the water column height are shown, and on the bottom, results on the leading water front position are shown. A mesh-refinement sequence $2^i(100 \times 30)$ for $i = 1, 2, 3$ are used for comparison. Here we have $a = 0.06$m and $g = 9.81$ m/s^2.

Table 1: Computational cost measured in CPU time

mesh	CPU time (sec)
100×30	1559
200×60	12392
400×120	100019

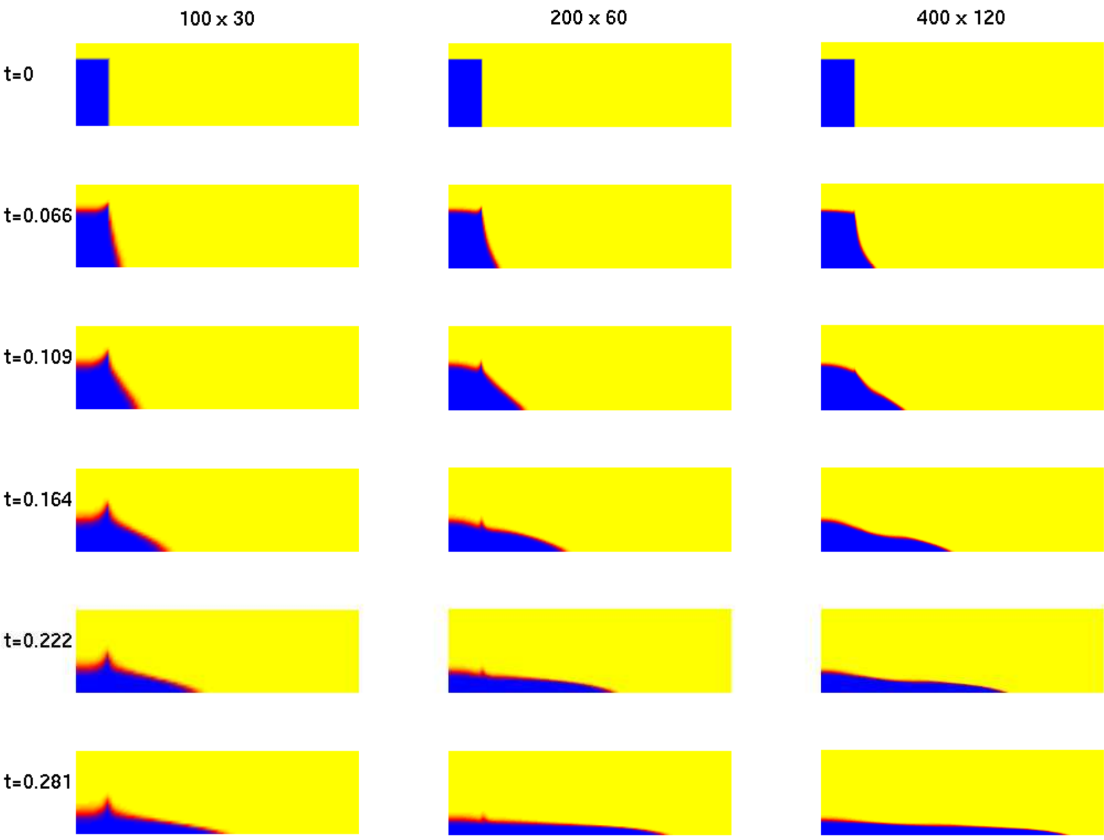

Figure 2: Pseudocolor plots of volume fraction for the broken dam problem. Results are shown at six different times obtained using the fluid-mixture algorithm with three different mesh points.